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Optimal light intensity for sustainable water and energy use in indoor cultivation of lettuce and basil under red and blue LEDs

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ABSTRACT

Indoor plant cultivation systems are gaining increasing popularity because of their ability to meet the needs of producing food in unfavourable climatic contexts and in urban environments, allowing high yield, high quality, and great efficiency in the use of resources such as water and nutrients. While light is one of the most important environmental factors affecting plant development and morphology, electricity costs can limit the widespread adoption of indoor plant cultivation systems at a commercial scale. LED lighting technologies for plant cultivation are also rapidly evolving, and lamps for indoor cultivation are often designed to optimize their light emissions in the photosynthetically active spectrum (i.e. red and blue), in order to reduce energetic requirements for satisfactory yield. Under these light regimens, however, little information is available in literature about minimum photosynthetic photon flux density (PPFD) for indoor production of leafy vegetables and herbs, while existing literature often adopts light intensities from 100 to 300 μmol m^{-2} s^{-1}. This study aims at defining the optimal PPFD for indoor cultivation of basil (*Ocimum basilicum* L.) and lettuce (*Lactuca sativa* L.), by linking resource use efficiency to physiological responses and biomass production under different light intensities. Basil and lettuce plants were cultivated at 24 °C and 450 μmol mol^{-1} CO_2 under red and blue light (with red:blue ratio of 3) and a photoperiod of 16 h d^{-1} of light in growth chambers using five PPFD (100, 150, 200, 250 and 300 μmol m^{-2} s^{-1}, resulting in daily light integrals, DLI, of 5.8, 8.6, 11.5, 14.4 and 17.3 mol m^{-2} d^{-1}, respectively). A progressive increase of biomass production for both lettuce and basil up to a PPFD of 250 μmol m^{-2} s^{-1} was observed, whereas no further yield increases were associated with higher PPFD (300 μmol m^{-2} s^{-1}). Despite the highest stomatal conductance associated to a PPFD of 250 μmol m^{-2} s^{-1} in lettuce and to a PPFD ≥ 200 μmol m^{-2} s^{-1} in basil, water use efficiency was maximized under a PPFD ≥ 200 μmol m^{-2} s^{-1} in lettuce and PPFD ≥ 250 μmol m^{-2} s^{-1} in basil. Energy and light use efficiencies were increased under a PPFD of 200 and 250 μmol m^{-2} s^{-1} in lettuce and under a PPFD of 250 μmol m^{-2} s^{-1} in basil. Furthermore, in lettuce grown under 250 μmol m^{-2} s^{-1} antioxidant capacity, phenolics and flavonoids were higher as compared with plants supplied with PPFD ≤ 150 μmol m^{-2} s^{-1}. Accordingly, a PPFD of 250 μmol m^{-2} s^{-1} seems suitable for optimizing yield and resource use efficiency in red and blue LED lighting for indoor cultivation of lettuce and basil under the prevailing conditions of the used indoor farming set-up.

1. INTRODUCTION

Indoor farming systems supplied with artificial lighting are claimed to substantially decrease the pressure on natural resources, with specific potentialities in reducing water used for food production (Graamans et al., 2018). Thanks to the use of hydroponics, the improved photosynthetic efficiency under the stable lighting and climatic conditions provided by the indoor environment and the possibilities for transpiration water recovery through air dehumidification, indoor cultivation may enhance water use efficiency (WUE, commonly

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